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6. AUTHOR(S)
Professor Birdsall

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
University of California, Berkeley
336 Sproul Hall
Berkeley, CA 94720

8. PERFORMING ORGANIZATION REPORT NUMBER

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13. ABSTRACT *(Maximum 200 words)*

Two 1d3v versions of XOOPIC were made, one directly from our 2d3v OOPIC, and the other, from scratch [which is attached, done mostly by a visitor, Dr. H. Usui, from Japan (wholly paid by his home institution)].
We are in the midst of improving XOOPIC with respect to microwave tubes by replacing non-e-beams regions with equivalent lumped element circuits.
We demonstrated quited a few means, physical and numerical, for speeding up particle codes (PIC-MCC) by factors of up to 10 to 100.
We also made a model/simulation to measure particles leaving a plasma, especially ions, in order to obtain their energy distributions and velocity angeles (called IED and IAD), as a function of the ratio of ion transit time [throught the plasma edge (sheath)] relative to the period of the RF driving the plasma.
While we have a good idea of the stability and accuracy of our ES and EM simulations in general (e.g., in Birdsall and Langdon text), it pays us to re-examine the cause and cures of errors of the Maxwell set the Newton-Lorentz set of equations, especially for relativistic particles.

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Object Oriented Formulations for Particle-in-Cell Simulations

AASERT Final Annual Report
FD49620-94-1-0387
7/1/97 - 6/30/98

Electronics Research Laboratory
University of California
Berkeley, California 94720-1774

Charles K. Birdsall, Principal Investigator
Emi Kawamura, Graduate Student Researcher

Air Force Office of Scientific Research
9/22/99

Introduction

The original proposal suggested a large number of tasks that might be done by students in the full 3 year AASERT. The list included:

- Development of a shell (integrated simulations system) with our EM PIC 2d3v codes as the core;
- OO organization of the software;
- Our graphics;

as well as

- Teaching such at AF labs;
- Teaching at ATRI.

It is always a challenge to balance these needs versus what we actually can do with students seeking MS or Ph.D. degrees, with the latter demanding demonstration of tackling new ideas, a common university dilemma.

Performance

We did some parts.

A. Two 1d3v versions of XOOPIC were made, one directly from our 2d3v OOPIC, and the other, from scratch [which is attached, done mostly by a visitor, Dr. H. Usui, from Japan (wholly paid by his home institution)]. One of these will replace EM1 and EM1BND (which are not maintained by us) in the Birdsall and Langdon book revision now starting.

B. We are in the midst of improving XOOPIC with respect to microwave tubes by replacing non-e-beams regions with equivalent lumped element circuits. Such should speed up the field solve in XOOPIC considerably, making it more useful in design, with many changes in parameters. The system will use Kirchhoff's voltage and current laws (maybe solved by SPICE) for the lumped elements and (probably) Poission's equation for the region of the e-beam.

C. We demonstrated quite a few means, physical and numerical, for speeding up particle codes (PIC-MCC) by factors of up to 10 to 100. Using fast PC's and WS's with normal run times of days and hours, we were able to get below an hour, or to a few minutes. This work is just about ready for publication, attached, as applied to RF discharges. Our methods are problem dependent, so will be somewhat different when applied to microwave tubes; however, the experience with about 10 successful methods will be applicable.

D. We also made a model/simulation to measure particles leaving a plasma, especially ions, in order to obtain their energy distributions and velocity angles (called IED and IAD), as a function of the ratio of ion transit time [through the plasma edge (sheath)] relative to the period of the RF driving the plasma. (The relevance of C, D to microwave tubes is that such are being filled with plasma to increase rate of gain and efficiency, without much attention paid to the formation and maintenance of the plasma, an area which tube engineers must learn.)

E. While we have a good idea of the stability and accuracy of our ES and EM simulations in general (e.g., in Birdsall and Langdon text), it pays us to re-examine the cause and cures of errors of the Maxwell set and the Newton-Lorentz set of equations, especially for relativistic particles.

Attached is a progress report on these errors as presented in a poster session at the most recent IEEE ICOPS, Monterey 1999 (but worked on during the AASERT period).

Attachments

A. Development of One-Dimensional XOOPIC, by Usui, Verboncoeur, and Birdsall
B. Physical and Numerical Methods of Speeding Up Particle Codes and Paralleling as Applied to RF Discharges, by Kawamura, Birdsall, and Vahedi.
C. Ion Energy Distributions in RF sheaths' Review, Analysis, and Simulation, by Kawamura, Vahedi, Lieberman, and Birdsall
D. Analysis of Error in PIC Simulations, by Cartwright, Verboncoeur, and Birdsall.

The AASERT students were Kawamura and Cartwright.